Experimental implementation of distributed management for service provisioning in an ASON/GMPLS testbed

C. Pinart, R. Muñoz, G. Junyent

Publication:	9th IEEE International Conference on Communications Systems (ICCS 2004)
Vol.:	-
No.:	-
pp.:	-
Date:	Singapore. September 6-9, 2004

EXPERIMENTAL IMPLEMENTATION OF DISTRIBUTED MANAGEMENT FOR SERVICE PROVISIONING IN AN ASON/GMPLS TESTBED

Carolina Pinart (1), Raül Muñoz (1), Gabriel Junyent (1, 2)

1 : Centre Tecnològic de Telecomunicacions de Catalunya (CTTC)
2 : Universitat Politècnica de Catalunya (UPC)

ABSTRACT

This paper focuses on the interactions of the ASON management plane of an optical network both with remote soft-permanent service provisioning and an optical control plane through integrating XML, SNMP and GMPLS based communication mechanisms and distributed approaches. Experimentation results with an ASON/GMPLS testbed[1] assess potential suitability of the overall distributed management approach for service provisioning due to its low delays and high flexibility.

1. INTRODUCTION

The accelerating growth of data traffic is motivating the research for more efficient, flexible, intelligent optical network architectures. In this direction, IP over Wavelength Division Multiplexing (WDM) is becoming accepted as one of the most promising candidates. Generalized Multi-Protocol Label Switching (GMPLS) is also thought to be an integral part of next-generation networks, especially as control plane of the Automatic Switched Optical Network (ASON) [1], because it renders optical networks intelligent. This evolutionary situation results in moving and adding optical management functions to the network, and is leading to a paradigm shift.

This paper focuses on the interactions of the ASON management plane both with remote soft-permanent service provisioning requests and the ASON control plane through integrating eXtensible Markup Language (XML) and Simple Network Management Protocol (SNMP) based communication mechanisms in the management plane, and coordinating these mechanisms with GMPLS, used in the control plane.

The remainder of this paper is organized as follows. Section 2 is devoted to the enabling technologies for achieving distributed management in the provisioning process of optical services. In Section 3, we outline the different levels of management information distribution. Section 4 describes the experimental ASON/GMPLS testbed, which combines SNMP, GMPLS and XML for service provisioning, while Section 5 illustrates the tests performed. In Section 6 we draw conclusions.

2. ENABLING TECHNOLOGIES FOR DISTRIBUTED MANAGEMENT OF SERVICE PROVISIONING

Some of the most popular technologies for distributed management are the Common Object Request Broker Architecture (CORBA), Java Remote Method Invocation, Distributed Component Object Model (DCOM) and Open Distributed Management Architecture. Since next-generation optical networks are expected to be heterogeneous, the main disadvantage of these technologies is that both the client and the server must have similar or the same engine and operating system for these technologies to work. Therefore, the above-mentioned approaches do not support true distributed components, that is, client and servers with different operating systems, running on different machines and networks.

Instead, XML based communication mechanisms are a very powerful technology, greatly motivating the idea of distributed computing. XML may rely on HyperText Transfer Protocol (HTTP), which has been, since its birth in the 1990s, a significant step in the evolution of distributed systems. The combination of HTTP and markup languages, such as hyper-text (HTML) or XML allows using the web for information sharing, and has changed the computing model from client-server to browser-application: a revolution. This “web revolution” has resulted in new possibilities for integration and platform independence, and has created a new distributed service model for management [5]. For instance, the Simple Object Access Protocol (SOAP) [2] sends XML requests over HTTP and receives responses back in XML. Since HTTP is the most extended communication mode in the Internet, SOAP seems an ideal protocol to enable integration of distributed systems. Note that XML provides information encoding, whereas HTTP provides transport of such information over any IP infrastructure, including IP/WDM. Therefore, XML/HTTP can be seen as part of the optical management service protocol.

On the other hand, XML is emerging as a de facto standard to exchange information over heterogeneous systems. Continuing with the previous example, this means that SOAP's use of XML to send/receive messages enables any system on any platform to read and process such messages. In the context of SOAP/XML, Web Services have the Web Service Description Language

---

[1] This work is part of the NetCat and TBONES (ITEA 02024 and FIT-070000-2003-936) R&D projects. The authors would like to acknowledge Jordi Sorribes for collaboration in the development of the GMPLS control plane used in this paper.

(WSDL), which defines, for each operation, the scheme for request and response XML string. The Web Service Meta Language (WSML) maps each operation COM's method.

3. ENABLING APPROACHES FOR MANAGEMENT INFORMATION DISTRIBUTION

We have approached management information distribution in three different "levels". The first level is the decentralization of connection requests, by means of user interfaces and remote soft-permanent requests (gateway manager, G, in Figures 1 and 2). This is elaborated in Section 4. The second level is the decentralization of the management system by using a gateway manager and distributed managers, as depicted in Figure 1. Instead of having a single Network Management System, NMS (centralized management), management systems are spread in the network. In Figure 1, there are two management domains (areas 1 and 2), each of which has a distributed manager connected to the gateway, in order to receive remote provisioning requests, and to the other distributed agents. Although this may resemble the typical network/domain management systems relation (UM and M in Figure 2a), there is no hierarchy among the gateway and distributed managers (G and M in Figure 2b). Each manager gathers information of its area, and interacts with other managers through distributed communications. An implementation example is CORBA deployment for inter-area management in the IST LION project [7]. The novel issue in our work is the absence of a single station to manage the network (called umbrella NMS in LION [7], UM in Figure 2a), and the use of other distributed communication than CORBA, making interactions more flexible.

In Figure 2a, the traditional management approach used in optical networks is shown. A top-level manager (UM) delegates management operation to mid-level managers (M), which are usually domain managers. Mid-level managers, in turn, manage optical devices (WDM, SDH equipment, etc.). Agents do not cooperate with one another. Figure 2b depicts our approach. Gateway and distributed managers in Figure 1 are mid-level managers (G and M, respectively), and agents are embedded not only in optical (active) hardware (OADM in Figure 1) but also in Optical Connection Controllers (OCC) [1]. Moreover, managers and agents cooperate. Finally, agents may be delegated (DA in Figure 2) if they act as a "proxy" to other management technologies, such as SNMP to TL1 conversion.

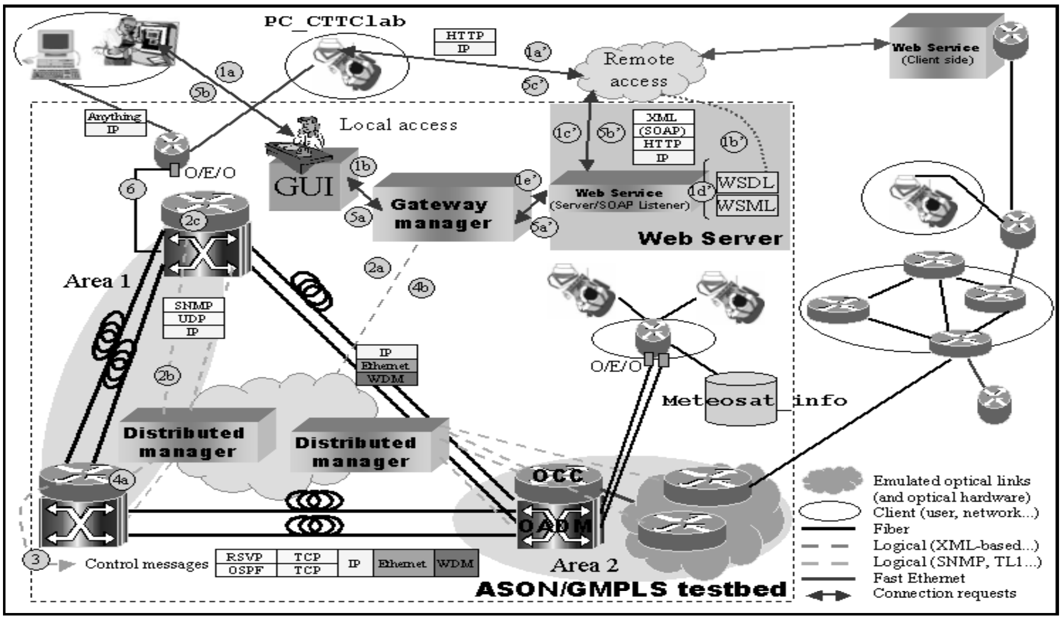


Figure 1. Local and remote SPC requests in the ASON/GMPLS testbed.

Last but not least, the third level of information distribution is the use of the GMPLS-OCC-CTTC Management Information Base (MIB) module in the control plane routers (OCCs). This module follows a complementarity-based approach for integrating management in GMPLS enabled WDM networks, focusing on management of control plane information related to service provisioning, as well as on function allocation between the optical management and control planes. Control and management plane interactions are complementary to allow the control plane for providing dynamic, fast, reliable, end-to-end IP paths over lightpaths through shared network management by the control (real-time) and management (near real-time) planes. This is described in [3] and [4], so no further details will be given in this paper.

According to [8], the combination of these three levels is an evolutionary step towards moving to a "strongly" distributed paradigm, compensating the necessary amortization of emerging technologies (XML, GMPLS) with proven Internet management

(SNMP). In "weakly" distributed paradigms, the management application processing is concentrated in a few nodes (i.e. distributed managers), and agents in the remaining nodes are "dumb" data collectors [8]. So, strongly distributed paradigms decentralize management processing down to every agent, in the sense that management tasks involve all agents and managers. "Strongly distributed" technologies include mobile code, distributed objects, and intelligent agents. Note that CORBA, RMI or ODMA, among others, are hierarchical paradigms based on distributed object technologies. Since our three-level approach encompasses horizontal delegation (Figure 2b), technologies needed must be according to cooperative paradigms [8]. This is further described in Section 4.4.

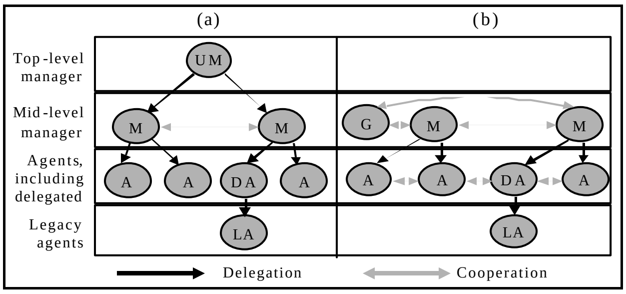


Figure 2. Traditional vs. future optical management.

4. EXPERIMENTAL ASON/GMPLS WITH XML BASED REMOTE SERVICE REQUESTS

The experimental testbed used in this paper is an optical network with Dense WDM (DWDM) and a GMPLS control plane to allow real-time dynamic configuration of optical channels between multiple clients (ASON) [3]. Clients may request optical connections in two ways: if they are UNI enabled (User Network Interface), they may request provisioning directly to the optical control plane, by sending appropriate messages to the OCC they are linked to. Otherwise, they may request optical services though the optical management plane. In turn, this process can be done in two ways, either locally or remotely.

4.1. Local connection requests

Figure 1 illustrates the request of connections through the management plane (soft-permanent connections, SPC), as well as the ASON planes [1] involved in the service provisioning process. In case of "local access" to the management plane, users will call the network operator (step 1a in Figure 1), who will introduce the necessary parameters in the Graphical User Interface (GUI). This request will be forwarded to the gateway manager (step 1b), and then management/control plane dialogue and GMPLS control plane signaling will start for the optical connection to be provisioned. [4] describes the distributed processing of the distributed manager and SNMP based agents (steps 2b, 2c and 4a in Figure 1). Section 4.4 describes the GMPLS mechanisms for establishing a connection (step 3). The result of these actions is displayed in the GUI (step 5a) and it is in that moment that the operator informs the user (step 5b), so that he/she can start data transmission. Currently, this process takes hours to weeks, due to the semi-manual operations needed.

4.2. Remote connection requests

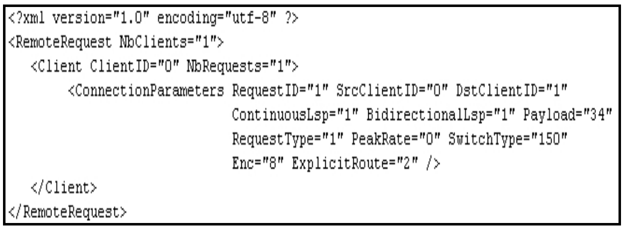
In case of "remote access" to the network, users connect to the testbed's web server. The testbed will provide a web service operation for users to request setup and teardown of optical connections with wavelength granularity. This XML based service accepts `ConnectionParameters` as input and returns the same tag with different attributes as output parameter. Figure 1 illustrates the server and client side processes involved in a "remote" connection request. Whenever a user (customer or network process) requests a connection, his/its SOAP client will initiate the setup/teardown process by making a SOAP request. In this process, the client will refer to the WSDL file which resides in the SOAP server, to form a valid SOAP request (steps 1a' to 1c' in Figure 1), and it will send the request to the testbed's SOAP server using HTTP.

The SOAP listener of the optical network will receive the SOAP request and will make sure the request adheres to the schema defined in WSDL (step 1d'). Once the request is validated, the listener will call in the COM component, residing in the gateway manager, with the help of the WSML file (step 1e'). Then, analogously to "local" requests, management/control plane dialogue and control plane signaling will take place. The result of this (steps 5a' and 5b') is packaged into an XML response (step 5c') in accordance with the scheme defined in WSDL. Finally, the client will receive the response, unpack it, process the result and start transmitting data (step 6 in Figure 1).

Figure 3 illustrates the XML package of a connection request, which matches the service provisioning objects of the OCC SNMP based agents, the GMPLS-OCC-CTTC-MIB module, so that they can be forwarded to the control plane distributed engine for connection establishment using GMPLS signaling [3]. Whenever a user requests a connection to the network, the ingress and egress user and/or service ID will be used. A typical example is *PC_CTTClab* for the ingress and *Meteosat_info* as the egress (Figure 1), in a scenario where a lab worker wants to know the weather forecast. Users (clients) requesting SPCs will be identified by the manager through their `ClientID`. The manager will eventually assign a client interface identifier if users have more than one link to the OCC they are linked to, e.g. if ingress user *PC_CTTClab* is linked to OCC 1 with interfaces 11 and 14. Clients unknown to the optical network will specify the Class of Service they have. *PC_CTTClab* is recognized by the network and therefore, no `ServiceClass` attribute is needed.

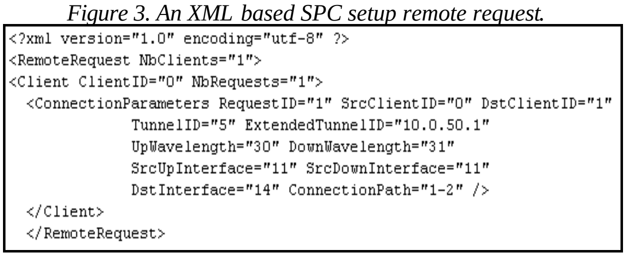
Each distributed manager allocates identifiers to ingress and egress clients, as well as EXTENDED_TUNNEL_ID and TUNNEL_ID for each SPC request, which do not appear in the initial XML (request) file but only in the response. Figure 4 illustrates the XML response file of the example given (Figure 3).

Since *PC_CTTClab* has more than one interface, the manager assigns the first one free (in Figure 4, `SrcUpInterface` and `SrcDownInterface`). Note that in the response, attributes `ExtendedTunnelID` and `TunnelID`, allocated by the manager, along with connection path and wavelength channels, calculated by GMPLS [3] are included (`UpWavelength`, `DownWavelength` and `ConnectionPath` in Figure 4).



```
<?xml version="1.0" encoding="utf-8" ?>
<RemoteRequest NbClients="1">
   <Client ClientID="0" NbRequests="1">
        <ConnectionParameters RequestID="1" SrcClientID="0" DstClientID="1"
                              ContinuousLsp="1" BidirectionalLsp="1" Payload="34"
                              RequestType="1" PeakRate="0" SwitchType="150"
                              Enc="8" ExplicitRoute="2" />
   </Client>
</RemoteRequest>
```

Figure 3. An XML based SPC setup remote request.



```
<?xml version="1.0" encoding="utf-8" ?>
<RemoteRequest NbClients="1">
<Client ClientID="0" NbRequests="1">
  <ConnectionParameters RequestID="1" SrcClientID="0" DstClientID="1"
             TunnelID="5" ExtendedTunnelID="10.0.50.1"
             UpWavelength="30" DownWavelength="31"
             SrcUpInterface="11" SrcDownInterface="11"
             DstInterface="14" ConnectionPath="1-2" />
  </Client>
  </RemoteRequest>
```

Figure 4. XML response file to a remote SPC request.

4.3. Data model for service provisioning

ITU-T Recommendations of X.700 Series or M.3010 are examples of conceptual (information) modeling of the management plane, including service provisioning. Such modeling is independent of specific implementation, and defines relationships between managed objects. Since control plane and transport plane elements (OCCs and OADM/OXCs, respectively) contain management agents, as well as a MIB and a message communication function, encompassing a management information protocol, the manager is able to access the information models of both the control and transport planes.

Therefore, in this paper we focus on a data model for service provisioning. [4] illustrates the OCC's service provisioning MIB module. As described in Section 3, this module is consistent with third-level management information distribution approach. Concerning the management information protocol, we have chosen SNMP [6] because it has been the industry reference for management since the last 1980s; SNMP agents are installed in almost any system to enable remote access to its components, making SNMP a de facto standard for network management [5].

4.4. Combining SNMP, XML and GMPLS

Unlike centralized and hierarchical paradigms, cooperative paradigms are goal-oriented. The price to pay is higher implementation complexity, so in order to alleviate this, we use SNMP, GMPLS and XML to form a constructive cooperation to deliver optical services (in this work, SPC).

The distributed nature of XML and its use in this work have been described. As for SNMP, Section IV.C describes the MIB module for provisioning, and [3] and [4] detail the distributed approach used in the dialogue of the management plane (SNMP) and the control plane (GMPLS). In short, since SNMP comes from centralized and hierarchical distributed paradigms [8], we make management complementary to GMPLS control through allocating functions to both planes so that no functionality or data is replicated, and flexible collaboration of the control plane's real-time and management plane's near-real-time mechanisms is achieved. Combining SNMP and GMPLS makes agents ”intelligent”, that is, autonomous, cooperative, reactive and proactive [8]. A description of GMPLS signaling follows.

When a new optical connection request arrives to a source (ingress) OCC, its GMPLS daemon creates a new Path State Block (PSB) for this session (identified by the destination node, TUNNEL_ID and LSP_ID) and initiates a RSVP Path Message containing Session and Lsp_Tunnel_IPv4_Sender_Template objects to unambiguously identify the Lambda-LSP request, a Generalized Label Request object to request a Lambda LSP indicating the type of payload, a IPv4_IF_ID_RSVP_HOP object to indicate which node and by which interface (link) is requested the lambda (this solution is only employed for unnumbered links), a SENDER_TSPEC object to specify the required bandwidth, and other relevant objects such as the Explicit Route (ERO), the Label Set or the Upstream Label objects. ERO allows to specify a strict path to the destination, being possible to specify not only the nodes along the path but also the links (fibers) and wavelengths in the fibers.

For SPCs, ERO's last hop must specify the destination (egress) OCC and the destination interface identifier. This information can provided by a routing protocol, such as Open Shortest Path First (link-state based) or Intermediate System to Intermediate System (distance-vector based), responsible for disseminating optical topology and network resources availability. In the absence of wavelength converters (`ContinuousLsp` in Figure 3), a lightpath must occupy the same wavelength on all the fiber links through which it traverses; this is known as the wavelength-continuity constraint and is very common in optical networks due to wavelength converters' technical limitations and high cost. Without routing protocols, the ingress node only knows the status of its attached links (local information), therefore the wavelength selection becomes more complicated, as the ingress node ignores which wavelength will be available along the entire path.

The Label Set object allows to guarantee the wavelength-continuity constraint in optical networks with local resource information, that is, it allows an upstream node to restrict the set of labels that a downstream node can choose, and ensures that a downstream node will assign a label that is acceptable to an upstream node. Label Set can be employed following two reservation schemes; forward and backward. In the former, all the wavelengths included in the label set are reserved along the forward path, whereas in the latter they are reserved in the reverse path. Another object that can be included in the Path message is the UPSTREAM_LABEL, to allocate a label on downstream signaling, allowing bidirectional optical connections.

After that, the Path message is sent along the selected route one hop at a time. Each intermediate node processes this message before forwarding it, creating a new PSB that associates all session parameters in each node traversed by the Path message. Finally, the egress OCC selects one label of the received label set using First-Fit or Random algorithm, and initiates a Resv message including the Generalized Label Object with the selected label, which configures/reserves optical switches at each hop towards the ingress OCC, following the route of the Path messages.

5. EXPERIMENTAL TESTS WITH REMOTE REQUESTS

We describe experimental tests performed in the ASON/GMPLS setting, which operates 8 DWDM channels/fiber at up to 2.5 Gbps, due to economic reasons. Links between OCCs are 35-km long (fiber pair) and the topology is a ring. The testbed's architecture is detailed in [3]. Tests feature an area (gateway and distributed managers embedded), XML runs directly on HTTP.

5.1. Test scenario

Users access the web page http://netcat.cttc.es to request connections through a form. The web server builds an XML file with the requests, and forwards it to the gateway manager. For each request, the manager builds a SNMP message containing the parameters depicted in Figure 3 plus those assigned by itself, and sends it to the ingress OCC. The SNMP agent of this OCC validates the message and forwards it to the GMPLS engine of the node (daemon). The connection is established through RSVP-TE signaling (Section 4.4) and the ingress agent is notified, along with the connection's wavelength channel(s) and path, assigned and calculated by the GMPLS based control plane. Then, the ingress OCC SNMP agent sends back a response to the manager, and a notification (SNMP trap [6]) containing the parameters assigned by the control plane). Finally, the gateway manager receives both the response and the notification and builds up the `<ConnectionParameters>` part of the XML response file (Figure 4). This response is sent back to the web server, which displays it for the user to start data transmission anytime.

5.2. Setup and teardown delays

In case of a single SPC request, average delays obtained for setup (in ms, 100 iterations, 2 Er, DCN heavily loaded) are 10 (XML parsing), 54 (SNMP pack/unpack, 3 for teardown) and 14 (GMPLS and SNMP agent, detailed in [3]): 74 ms in total. To emulate multiple users we have compiled several XML files containing 500 setup and teardown requests. Lightpath requests are bidirectional, Premium class, and served as they appear in the XML files. Traffic distribution among nodes is uniform. Figure 5 depicts provisioning delays obtained for different traffic loads.

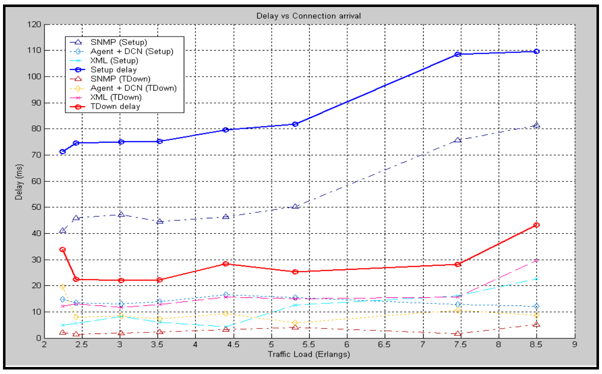


Figure 5. Delays vs. connection arrival.

5. CONCLUSIONS

Control planes of next-generation IP/WDM networks can make use of GMPLS related protocols and their extensions for optical networks, which raises novel management challenges. XML is emerging as a de facto standard to exchange information over heterogeneous systems. SNMP has been the industry standard for network management since the last 1980s. Results of combining XML, SNMP and ASON/GMPLS provisioning processes and a multi-level distributed approach are promising in the sense that they assess distributed management and may lead to provisioning delays compliant even with restrictive Service Level Agreements (less than 1 min), once SOAP is deployed.

REFERENCES

[1] ITU-T G.8080, "Architecture for the Automatically Switched Optical Network (ASON)", November 2001.

[2] Mitra, N.; "SOAP Version 1.2 Part 0: Primer", World Wide Web Consortium (WWC) Recommendation, June 2003.

[3] Muñoz, R.; Pinart, C.; Martínez, R.; Sorribes, J.; Junyent, G.; "Experimental demonstration of two new GMPLS lightpath setup proposals for soft-permanent connections over a unidirectional OADM ring implemented on EMPIRICO testbed", *in Proc. III Workshop MPLS Networks*. Girona, 2004.

[4] Pinart, C.; Junyent, G.; "On implementing a management plane for service provisioning in IP over reconfigurable WDM networks", *in Proc. ONDM 2004*, pp. 465-480. Ghent, 2004.

[5] Westerinen, A.; Bumpus, W.; "The continuing evolution of distributed systems management", *IEICE Transactions on Information & Systems*, Vol. E86-D (11), November 2003.

[6] Harrington, D. Ed.; "An architecture for describing SNMP management frameworks", IETF RFC2571, April 1999.

[7] Manzalini, A., et al.; "Experience of the IST LION Project "Layers Interworking in Optical Networks" in switched optical networks", Telecom Italia Lab (TILAB), March 2002.

[8] Martin-Flatin, J. P.; Znaty, S.; "Two taxonomies of distributed network management paradigms", *Network and Systems Management: Emerging Trends and Future Challenges*, Plenum Press, New York, NY, USA, 1999.